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Assessing the policy scenarios for the Ecosystem Water Food Energy (EWFE) nexus in the Mediterranean region

Armağan Aloe Karabulut[a,*], Angel Udias[b], Olga Vigiak[b]

[a] Ministry of Food Agriculture and Livestock, DG Agricultural Research & Policies, GIS & RS Center, Istanbul Yolu, 06170 Yenimahalle, Ankara, Turkey
[b] European Commission, Joint Research Centre, Directorate D-Sustainable Resources, Via E. Fermi 2749, 21027 Ispra, VA, Italy

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ABSTRACT

Increasing demand and the current unbalanced sectorial attribution of natural resources induce drastic depletion of natural capital. There is a need for bridging sectoral policies into interdisciplinary sustainable management strategies in the Mediterranean region. The complex interactions between ecosystems, food, energy, and water sectors are calling for an integrated approach for supporting impact assessments and decision-making. We aimed to investigate the coherence among the sectoral policies, either supporting or conflicting with each other, on cross-cutting strategies and their impacts on ecosystem and their services. We address ecosystem services as a fourth component besides energy, water, and food sectors in the nexus approach. We collected expert opinions on eleven sectoral policies that cover different disciplines (water, agriculture, energy, economy, and environment). Based on the opinion of the experts, we developed several multi-criteria analyses (MCA) to assess sectoral policy impacts on cross-sectoral strategic targets. Considerable consistency was found in ranking the eleven policies when considering using nexus or cross-cutting strategies criteria, or when considering positive or negative impacts. The EWFE nexus dimension allowed to better distinguish potential synergies or conflicts between sector policies because it provided a framework in which the role of ecosystem service was more explicit. Interestingly, restoring ecosystem and green infrastructures policy ranks among the top policies in all MCAs but according to the experts its probability of successful implementation is among the lowest. The results show that sustainable use of ecosystem services and conservation of the biodiversity are an indispensable pillar to achieve successfully sectoral development goals.

1. Introduction

Natural resources, particularly water and land, are shared by different economic sectors and serve many social needs. Under the fast growing population push, the increasing demands of natural resources induce unbalanced sectoral allocations and drastic depletion of natural capital, which may create conflicts between sectors, populations, and even neighbouring countries (Scozzari and El Mansouri, 2011). Governments develop sectoral policies to support food and energy production as well as water provision (CEQ, 2009). However, despite the inherent interconnections between food, water, and energy production, agencies often work in a fragmented and isolated way. Poor sectoral coordination and institutional fragmentation have triggered an unsustainable use of resources and threatened the long-term sustainability of food, water, and energy security, and thus the achievement of the global Sustainable Development Goals (SDGs).

Additionally, ecosystem services (ESS) are essential to humanity and its socio-economic activities. ESS are not only integrated in biodiversity policies as a result of the Millennium Ecosystem Assessment (MA, 2005), but are also linked to other sectoral policies, business decision making and sustainable economic growth strategies at global, regional and national level (Fisher et al., 2008; De Groot et al., 2010; TEEB, 2010; UNDP, 2016; European Commission, 2011). Since ESS are cross-sectoral, a sustainable use of natural resources that would preserve ecosystems, biodiversity and their services, necessitates interdisciplinary sustainable management and economic strategies (Costanza et al., 1997; Braat and De Groot, 2012; Bond et al., 2017). In this regard, there is a great effort specific to integrating concretely the ecosystem services into the policy and decision making mechanisms (Egoh et al., 2008; Braat and De Groot, 2012; Maes et al., 2012a;

Abbreviations: PoS, the probability of successful implementation; (Policy) SCs, policy scenarios; ISEG, impact on the socio-economic growth; ICCR, impact on climate change resilience; IGE, impact on green economy; IER, impact on ecological resilience

* Corresponding author. Fax: +90 0312 327 28 93.
E-mail address: armagank@tgae.gov.tr (A.A. Karabulut).

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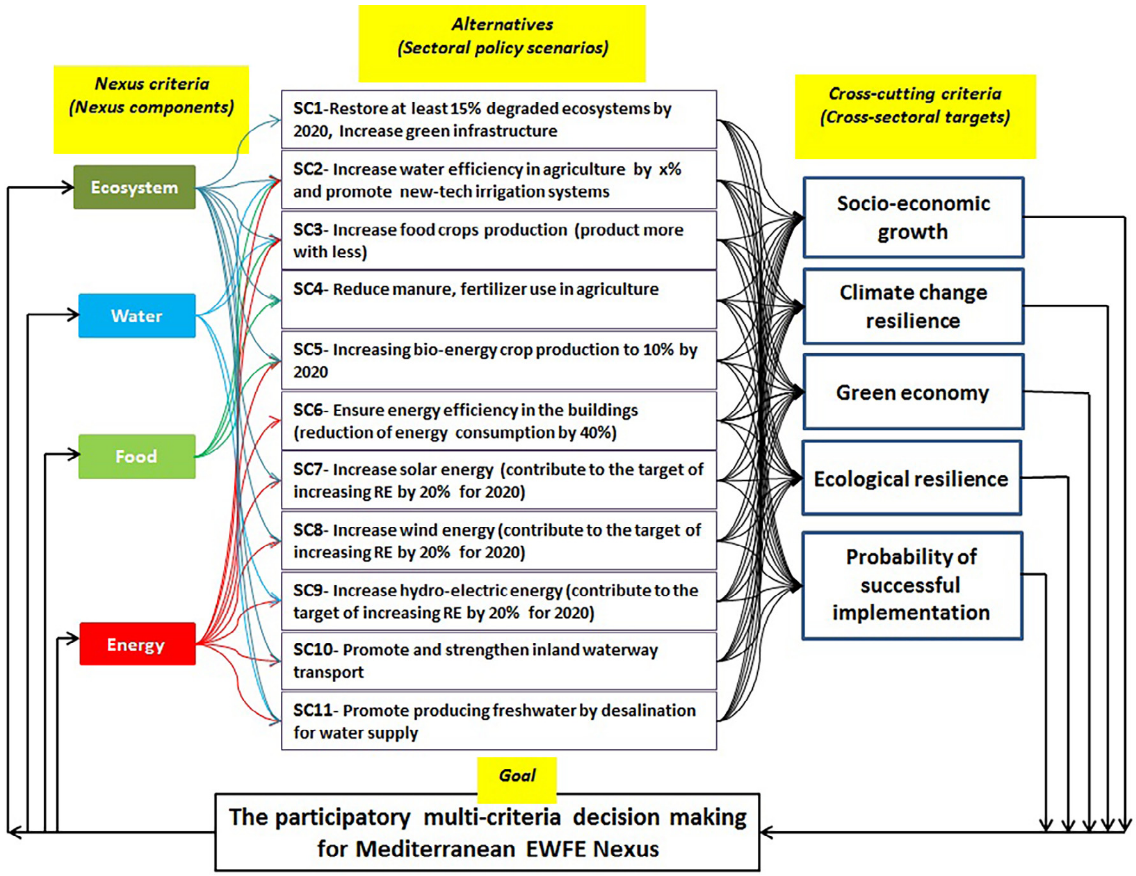

Fig. 1. The participatory multi-sectoral decision making for the most advantageous SCs under MCA techniques in the Mediterranean region.

Bateman et al., 2013; Costanza et al., 2017) starting with defining and classifying the ecosystem services (Fisher et al, 2009; Haines-Young and Potschin, 2013) followed by mapping, quantifying and valuing (Crossman et al., 2012; Burkhard et al., 2012; Maes et al., 2013; Costanza et al., 2014; La Notte et al., 2015; Karabulut et al., 2016; Liquete et al., 2016), and analysing trade-offs between the sectoral demands (Rodríguez et al., 2006; Maes et al., 2012b; Howe et al., 2014).

Greater policy coherence among the three sectors of water, food, and energy is critical for securing basic human needs, but also to move towards a more sustainable and efficient use of resources. A major shift in the decision-making process in the direction of a more holistic stance and institutional mechanisms to coordinate and strengthen complementarities among the four sectors are required. This call for better integrated policy approach is at the basis of the Ecosystem Water Food Energy (EWFE) nexus concept (Hoff, 2011; Bazilian et al., 2011; Rasul, 2014; FAO, 2014; Bizikova et al., 2013; Kurian and Ardakanian, 2015; Karabulut et al., 2016, 2017; Vanham, 2016). The Nexus approach helps highlight cross-sectoral interactions and facilitate the adoption of integrated planning, emphasizing the role of participatory multi-sectoral decision-making. The approach can also help identify the best way to allocate ESS between competing needs, in order to support agreed development pathways. Some studies typically identify key trade-offs between policy strategies and use of services, as well as potential synergies (De Groot et al., 2010; Granit et al. 2013). On one hand, synergies can point to “win–win” solutions; on the other hand, trade-offs need to be mediated (Daily et al., 2009; Braat and De Groot, 2012; Granit et al. 2013). Despite the efforts and initiatives to integrate the ecosystem services into policy and decision making mechanisms, the complex interrelationships among sectoral policies, sometimes supporting, sometimes conflicting with each other, make difficult to combine assessments into a single framework (De Groot et al., 2010; Morrison-Saunders et al., 2015). Tools and methods bridging impacts of interrelated policies are being developed to minimize cross-sectoral conflicts, maximize synergies, and achieve policy objectives using a systems approach (Morrison-Saunders et al., 2015). Indeed, managing competing sectoral demands jointly may highlight synergies and trade-offs, and reduce negative impacts on ecosystem services (Bizikova et al., 2013; Geneletti et al., 2015; Karabulut et al., 2017).

A major issue in carrying out a cross-sectoral analysis of any given policy is the difficulty of assess the impact of that policy on the territory. The application of biophysical models, where possible, is often time and resource consuming, fraught by uncertainty, and potentially impaired by lack of data. An alternative solution is to resort to expert opinion even though it may be biased by subjective perspectives. Expert opinion in support of decision making plays a large role in science and engineering. Increasingly, expert opinion is recognized as robust qualitative data when elicited with scientific rigour (Goossens et al., 2008). Furthermore, it can be argued that the use of expert opinion in relation to technical problems is not only unavoidable, but also desirable (Keeney and von Winterfeldt, 1989).

The Mediterranean region is particularly vulnerable to over-allocation of natural resources, particularly water, which is already scarce to meet all sector demands and whose exploitation is likely to worsen in the future given climate change projections. This study aims at investigating the coherence among sectoral policies on the Ecosystem Water Food Energy (EWFE) nexus for the Mediterranean region. Expert opinion was used to inform a two-dimensional multi-criteria analysis (MCA) assessment to provide an integrated tool supporting the nexus in the region. MCA helps in bringing expert knowledge to the scoring process, and understanding stakeholder opinion (Saaty, 1990; Meyer and Booker, 2001; Gambelli et al. 2010; Tavana, 2003; González et al., 2013).

2. Methods

Multi-criteria decision making (MCDM) or multi-criteria analysis (MCA) refers to making choice or rank alternatives from among a finite set of decision alternatives in terms of multiple, usually conflicting criteria. The main steps in MCA are the following (Hwang and Yoon, 1981): identify and structure the problem; establish system evaluation criteria; select or generate the alternatives for attaining the goals; evaluate alternatives in terms of criteria; estimate the overall priority values to rank the alternatives.

We conducted several multi-criteria analysis (MCAs) based on the Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS), a well-established methodology (Hwang and Yoon, 1981) that deals with multi-criteria analysis and allows for the participation of multiple stakeholders (including individual and group preferences). In our study, MCAs were applied to prioritize different sectoral policies (SCs) in the Mediterranean under two different criteria dimensions (Fig. 1) and considering either positive or negative impacts. The component of the framework were: (i) definition of two overarching criteria groups (dimensions), (ii) identification of key sectoral policies, and (iii) elicitation of expert opinions. In addition to the prioritization of the policy scenarios, we examined the interrelationships among each criterion within two dimensions separately in order to identify potential synergies and conflicts. Correlation analyses were also performed in order to seek relations between policies and dimension criteria. We produced Spearman's rho and Kendall's tau correlation matrix according with our data structure, so as to perform reliability analysis (Barrett, 2001). Additionally, we performed non-parametric Chi-square and the Fisher's exact tests in order to examine the relations between SCs and the two dimensions criteria, based on the evidence that the scales are ordinal and the variances were not significantly different (Stevens, 1946; Rao and Sinharay, 2007.

2.1. The two-dimension criteria

The two dimension criteria schemes were defined as (1) the EWFE nexus and (2) cross-cutting (sectoral) strategies criteria (Fig. 1). For the EWFE, we define the ecosystems and their services as the fourth Nexus component besides energy, water and food sectors, which is compatible with the expression of Aichi Biodiversity targets (CBD, 2010) that are embedded in the SDGs (Table SM1). Thus, we structured our assessment by identifying four nexus pillars: ecosystems, water, food, and energy security.

Cross-cutting criteria were defined based on global and European sectoral strategies. We believe that the achievement in the SDGs implementation, particularly in the SDG 14 and 15, relies on primarily accomplishing the Aichi biodiversity targets (CBD, 2010). Therefore, in this study ecological resilience represents the conserving the ecosystems, while green economy addresses the natural capital of ecosystem services. We defined four main cross-cutting criteria consistent with the European Commission's strategic targets (COM/2015/610 final; European Commission, 2015) as follows:

- ISEG: Impact on Socio-Economic Growth (e.g. job creation and growth (COM/2015/610 final; European Commission, 2015).
- ICCR: Impact on Climate Change Resilience, i.e. the ability of society to survive and recover from the effects of climate change, for instance, the ability of farmers to maintain their agricultural production in spite of climate change (Filho, 2015).
- IGE: Impact on Green Economy ("sustaining economic, environmental and social well-being by green sectors such as renewable energy, energy efficiency, clean technology and water"; Voumik and Shah 2014). The natural capital of ecosystem services and accordingly ecological resilience can be achieved in accordance with economic growth through greening the economy (Brock and Taylor, 2004).
- IER: Impact on Ecological Resilience (Sustainable use of services while conserving the ecosystems, defined by Gunderson (2000) as "the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures".).

Additionally, the Probability of Successful Implementation (PoS) of policy scenarios in the Mediterranean region was considered as an independent element to be combined with both criteria dimensions.

2.2. The sectoral policy scenarios (SCs)

Kukrety et al. (2013), Delgado-Galván et al. (2014) and Petrini et al. (2016) recommend a maximum of 10 alternatives to avoid confusion and inflated uncertainties that can occur with a large number of comparisons. After reviewing and listing the relevant EU sectoral policies, measures and actions, we selected eleven core policies (SCs) with the largest cross-cutting impact. The SCs (alternatives in MCA) selected for this study are:

- SC1, Restore (at least 15%) degraded ecosystems by 2020 and increase green infrastructure,
- SC2, Increase water efficiency in agriculture by x%, promote new-tech irrigation systems and help to modernize farms,
- SC3, Increase food crops production,
- SC4, Reduce manure, fertilizer use in agriculture,
- SC5, Increase bio-energy crop production to 10% by 2020,
- SC6, Ensure energy efficiency in buildings (reduction of energy consumption by 40%),
- SC7, Increase solar energy (contribute to the target of increasing renewable energy (RE) by 20% for 2020),
- SC8, Increase wind energy (contribute to the target of increasing RE by 20% for 2020),
- SC9, Increase hydro-electric energy (contribute to the target of increasing RE by 20% for 2020),
- SC10, Promote and strengthen inland waterway transport,
- SC11, Promote producing freshwater by desalination for water supply.

2.3. Eliciting expert opinion

MCA method allows multiple stakeholders' participation in the prioritizing process (Kurka and Blackwood, 2013; Handfield et al., 2002; Meyer and Booker, 2001; Saaty, 1990). The use of expert judgment in decision-making processes usually provides good results with a much lower cost than other alternative assessment techniques (Kerkhof, 2001; Teixeira et al., 2010). Within the Mediterranean region, 23 experts from different countries, background, expertise, and professional roles participated to the survey (Table 1). In the expert group, 7

Table 1
The participant groups and countries for the Mediterranean region.

Sectoral stakeholder groups	interest groups	Countries
Academic, Policy maker/government, Private sector/business, Non-profit organization, Others	Water (7), agriculture (6), energy (2), economy (4), ecosystems-ecology (4)	Croatia, Republic of Cyprus, Egypt, France, Greece, Italy, Lebanon, Republic of Macedonia, Morocco, Palestine, Portugal, Spain, Tunisia, Turkey

Categories	No opinion	Negatively	Neutral	Positively
Scale				
S1				
S2				
.				
.				
S11				

Fig. 2. Three-points Likert scale used for the first section of the questionnaire.

respondents belonged to the water, 6 from agriculture, 4 from ecosystems, 4 from economy, and 2 from energy sector.

A questionnaire was prepared to elicit the experts' opinions from different disciplines (water, agriculture, energy, economy, environment-ecology, policy makers, scientists, NGOs etc.) on possible synergies and controversies among the selected policy scenarios (Nilsson et al., 2012), and their possible impacts on both dimensions' criteria. The questionnaire was specific for the Mediterranean region. In the first section of the questionnaire a three-point Likert scale (ordinal rating; McIver and Carmines, 1981; Allen and Seaman, 2007), namely, positive, negative or neutral, was proposed to rate the impacts of the policy SCs on the nexus criteria in 44 questions (Fig. 2).

A second group of 44 questions in the survey was focused on possible impacts of SCs on the cross-cutting criteria. In this case, a five-points Likert scale varying from very negative to very positive, was proposed (Fig. 3).

Additionally, 11 questions (one per policy) were asked to gauge the experts' opinions on the probability of successful implementation of the policy in the Mediterranean region. Also in this case, a five-points Likert scale from very low to very high probability was used (Fig. 3). Finally, advices and additional comments of the experts were also collected.

2.4. Data analysis (policies assessment)

In the first step of the data analysis, the expert opinions were processed by means of contingency tables and graphically shown as stacked bar charts. These give an overview of the preference rates on each SC for each dimension separately.

Each data entry (Likert scale choice of an expert) is an ordinal data; however the rate of experts who choose a specific categorical answer approximates a continuous variable (in the range 0–1; Sullivan and Artino, 2013). The continuity of the variable is not necessary to use the rates as attributes with which to evaluate a criterion within the multi-criteria analysis (it is a frequent practice in this type of analysis to use ordinal scales), but it is a requirement to perform correlation analysis.

The TOPSIS multi-criteria method was applied in order to rank policies according to perceived impacts against both dimensions criteria. The rate of expert who chose one specific categorical answer in the Likert scale was used as attribute to assess the potential possible impact in each criterion of the dimension. We considered separately the positive impacts (+) of each policy or its negative impacts (−), resulting in two rankings of policies for both the EWFE and the cross-cutting strategies dimensions. For the cross-cutting strategies, for which original data was expressed on a five points Likert scale, the positive impacts were obtained by merging positive and very positive answers, while the negative impacts considered both negative and very negative scores. Results of this analysis were consistent with those obtained using only very positive or very negative answers (shown in Supplementary materials). Correlation analyses between the SCs were performed to investigate potential synergies and conflicts between SCs.

In all the cases, the TOPSIS method was initially applied considering all the criteria as equally important. This assumption ensures neutrality regarding the importance of each criterion. However, a dependency analysis between the criteria and SCs was performed to limit or avoid double-counting (Keeney and Raiffa, 1993).

Data analyses were performed in R language (R Core Team, 2013) and graphed in excel. Excerpts from the questionnaire and additional calculations can be found in the supplementary materials.

The potential weaknesses in this approach are related to the fact that scoring the impacts can be subjective, depending on the experts involved. In order to the importance of the experts opinion subjectivity, the comparison between the MCA performed based in different criteria and attributes helps to increase the robustness of the results.

Categories	I have no opinion	Very negative	Negative	Neutral	Positive	Very positive
Scale						
Impact on socio-economic growth						
Impact on climate change resilience						
Impact on green economy						
Impact on ecological resilience						

Categories	I have no opinion	Very low	Low	Neutral	High	Very high
Scale						
The probability of successful implementation in your region may be						

Fig. 3. Five-points Likert scales used for the second section of the questionnaire.

Fig. 4. Impacts of SCs on each EWFE nexus criterion.

3. Results

The judgements of 23 selected experts from the Mediterranean region were processed. The categories assigned by the experts were summarized in the supplementary material (Table SM2 and Table SM3).

3.1. Scoring of policies for EWFE nexus criteria

In relation to Nexus criteria (Fig. 4), we observed that SC2 was considered the most positive alternative (with level of 95.7%) for water and the second best alternative for food and ecosystem security. On the other side, SC2 does not have high percentage of positive rates (65%) with regards to the energy security. The most positively valued policy regarding the ecosystem and water security was SC1 with agreement of 100% and 91.3%, respectively, but SC1 scored low for energy criterion (31.8%). The most positive impact for energy security were SC7 with agreement of 100%, SC8 and SC6 with the same agreement of 95.7% (Fig. 4).

On the other side, two policies were considered most negative on the Nexus according to the experts. SC5 rated negative impact in food (60.9%), ecosystems (50%) and water security (47.5%). SC3 was judged to have equally negative impact rates for ecosystems and water security (50.4%), and in energy security (30.4%). In addition, SC11 rated very negative because of the high negative impacts in energy and ecosystems (66.7% and 40.9%). The policy SC10 on ecosystem security generates large disagreement among the experts, divided between similar negative or positive impacts; divided opinions were also detected for the SC3 policy in the energy security criteria (Fig. 4).

Pearson's correlations between the four nexus criteria were calculated to understand if there is a risk of double-counting in the MCA. One significant correlation (0.84) was observed between water and ecosystem security within the nexus criteria (Table 2).

The correlations among policy scenarios are illustrated in Table 3.

Table 2
Correlations between the EWFE nexus criteria.

	Water	Food	Energy	Ecosystem
Water	1	0.30	0.17	0.84
Food		1	−0.29	0.09
Energy			1	0.37
Ecosystem				1

There is almost complete agreement among the experts in considering that increasing solar energy (SC7) and wind energy production scenarios (SC8) present very similar impact in all sectors of the Nexus dimension. In addition, the experts substantially agreed that increasing bioenergy crop production (SC5), energy efficiency in the buildings (SC6), and increasing solar energy (SC7) have similar impacts (correlation > 0.90) on the nexus. On the other hand, experts consider that there are conflicting impacts on the nexus criteria (correlation $= -0.99$) between restoring degraded ecosystems (SC1) and promoting inland waterway transport (SC10). This is easy to appreciate also in Fig. 4. Similarly, conflicts could be detected (correlation < -0.91) for the policy pairs SC3–SC4, SC6–SC11 and SC1–SC9.

3.2. Scoring of policies for cross-cutting criteria

With regards to cross-cutting strategies dimension, it is observed that the policy SC6 gets the highest positive impact according the ISEG and ICCR, and the second best one for the IER and IGE (Fig. 5). SC7 is considered the best policy for green economy (IGE) and ICCR, the second best in ISEG, and the third about IER. Under the IER criterion, the best impact score is achieved by SC1, which gets also good rates for ICCR. Conversely, SC10 had lowest positive impact (Fig. 5) regarding ICCR, IER and IGE criteria.

SC11 scored poorly on positive impacts, but appeared to be also one

Table 3
Correlations among the policy scenarios based on the nexus part of the questionnaire.

NEXUS	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11
SC1		0.82	−0.46	0.54	−0.68	−0.35	−0.49	−0.47	**−0.91**	**−0.99**	0.40
SC2			0.84	0.02	−0.90	−0.78	−0.68	−0.62	−0.86	−0.85	0.85
SC3				**−0.96**	−0.34	−0.63	−0.53	−0.52	0.08	0.48	0.40
SC4					0.24	0.60	0.36	0.34	−0.22	−0.53	−0.47
SC5						**0.91**	**0.93**	0.89	0.88	0.67	−0.81
SC6							0.85	0.80	0.61	0.36	**−0.92**
SC7								**0.99**	0.80	0.44	−0.63
SC8									0.79	0.41	−0.54
SC9										0.88	−0.52
SC10											−0.45

Correlation is significant at the 0.05 level.

of the worst policies when looking at negative impacts, being perceived as detrimental especially for the IGE and IER criteria, and the third more negative under ICCR. The SC3 and SC5 are considered to be the worst scenarios (with the most negative impact) for the climate change resilience (ICCR), and among the worst for IGE and IER.

The policy SC5 generates large disagreement among the experts, similarly divided between negative or positive impacts on the ecological resilience criterion IER (Fig. 5), whereas the majority of the experts (70% in IGE and 60% in ICCR) agree that the policy SC10 has neutral impact on the green economy (IGE) and ICRR.

Pearson's correlations between the four criteria of cross-cutting dimension (Table 4) indicated one very significant correlation (0.94) between the ICCR and IGE and two high (but not significant) correlations between ICCR-IER and IGE and IER, so it seem that three of the four criteria are not really independent, which could introduce a bias in the multi-criteria analysis.

Therefore, to eliminate the possibility of bias in the analysis, when the weight of ICCR and IGE was reduced to be less than 0.1 and the PoS increased to be more than 0.4, SC6 became the second best alternative following SC7 (see Fig. SM3 in the supplementary material). With these new weights, the SC10 still remains the worst scenario, and it needs to be setup to a very extreme value (weight for ISEG > 0.45, ICCR < 0.1, IGE < 0.1, IER < 0.2 and probability of success < 0.15) for SC10 to improve its ranking (see Fig. SM4 in the supplementary material).

The correlations among the policies on cross-cutting criteria are

Table 4
Correlations among the cross-cutting criteria.

	ISEG	ICCR	IGE	IER	PoS
ISEG	1	0.61	0.69	0.29	0.50
ICCR		1	**0.94**	0.83	0.27
IGE			1	0.75	0.31
IER				1	0.13
PSI					1

Correlation is significant at the 0.05 level.

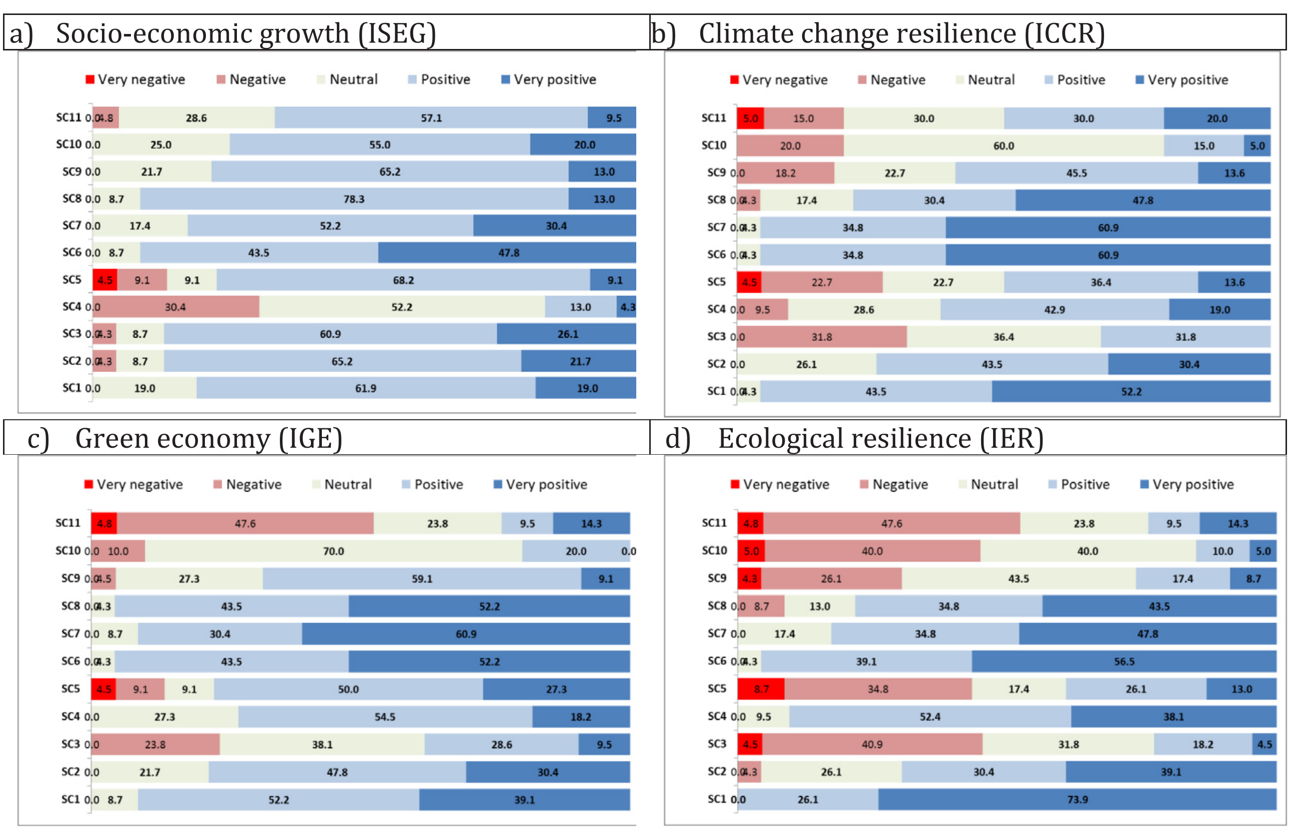

Fig. 5. Impacts of SCs on each cross-sectoral criterion.

Table 5
Correlations among the policy scenarios based on the cross-cutting part of the questionnaire.

Cross-cutting	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11
SC1		−0.48	−0.20	0.88	0.04	**0.94**	**0.94**	0.83	−0.24	0.20	−0.60
SC2			0.14	−0.67	0.49	−0.26	−0.15	−0.12	0.68	0.33	0.76
SC3				−0.51	0.17	0.06	−0.19	−0.28	0.66	0.77	0.72
SC4					−0.02	0.71	0.75	0.77	−0.50	−0.17	−0.89
SC5						0.29	0.29	0.55	0.79	0.62	0.31
SC6							**0.96**	0.86	0.10	0.52	−0.32
SC7								**0.92**	0.02	0.37	−0.40
SC8									0.11	0.33	−0.45
SC9										0.85	0.80
SC10											0.46

Correlation is significant at the 0.05 level.

illustrated in Table 5. There is almost no conflicting issue between policies (the higher correlation is −0.89 between the SC4 and SC11). Regarding the synergies between the SCs, the strongest relationship is observed between the pair of SC6-SC7 (correlation > 0.96), followed by the pairs of SC1-SC6 (correlation > 0.94) and SC1–SC7 (correlation > 0.94; Table 5).

To complete the correlation analysis, correlations between the two dimensions criteria indicate remarkable correlation between the Ecosystem criteria of the EWFE dimension and all the cross-cutting criteria except the impact in socio economic growth (ISEG) (Table 6).

3.3. Probability of success of policy implementation

Fig. 6 summarise the expert opinion about the probability of success of policy implementation in the Mediterranean region. SC8, SC2, SC7 and SC11 are perceived as the policies whose implementation is most likely to succeed, with at least 50% of the experts attributing high to very high probability of success. Instead, according to the experts, the policies SC1, SC10, SC4 and SC5 have low to very low probability of success. In the case of SC1 and SC10 this found at least 50% of agreement among experts.

3.4. MCA ranking of policies

Table 7 summaries the preference ranking of policies according to the two sets of criteria considered individually and different indicators/attributes, according to the expert opinion, calculated when equal importance is given to all criteria. Additionally, Table 7 reports policy ranking based on the probability of success of implementation.

Applying the TOPSIS multi-criteria analysis for the EWFE on positive impacts, policy scenario SC2 (increasing the water efficiency in agriculture by promoting new-tech of irrigation systems) has the best impact on whole nexus criteria, followed by SC1, SC8, SC7 and SC6 (Table 7, EWFE+). The scoring of these four policies were very similar (from 0.57 to 0.64 in a 0–1 range). At the opposite end, SC10 and SC5 have the least positive impact, with similar low scores. When looking at the negative impacts (EWFE-column in table 7), the SC5 (Increase bioenergy crop production) is also the policy that provides the highest negative impact followed by the SC11. Therefore, according to the expert opinion SC5 is the policy which most adversely affects the EWFE nexus, because has the least positive impact and the worst negative impact. In terms of least adverse policies (top position in EWFE-column of table 7), the SC6 (Ensure energy efficiency in buildings) is the least negative on EWFE nexus criteria, followed by SC1, SC7, SC8 and SC2. All the five policies get very similar score.

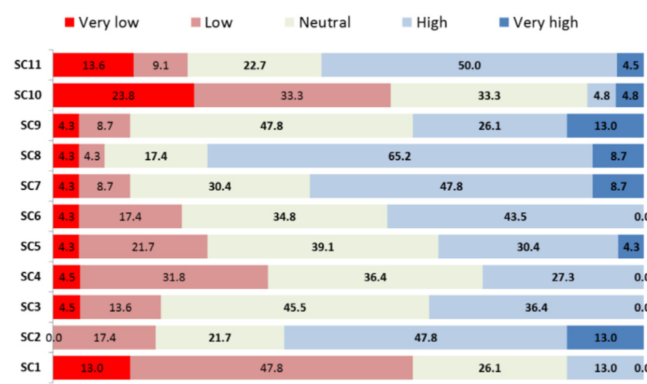

Fig. 6. Impacts of SCs on the success probability of implementing the scenarios in the region (PoS).

Table 7
TOPSIS policy rankings (best to worst) for the EWFE and cross-cutting strategies (CS) dimensions, when considering positive (+) or negative impacts (−; ranked from the least to the most negative). PS indicates the probability of success in the policy implementation.

Rank	EWFE +	EWFE -	CS +&v+	CS -&v-	P.S. +&v+	P.S. -&v-
1	SC2	SC6	SC6	*SC6*	SC8	SC8
2	SC1	SC1	SC1	*SC1*	SC2	SC9
3	SC8	*SC7*	SC7	*SC7*	SC7	SC7
4	SC7	*SC8*	SC8	*SC8*	SC11	SC2
5	SC6	SC2	SC2	SC2	SC6	SC3
6	SC11	SC10	SC4	SC9	SC9	SC6
7	SC3	SC4	SC5	SC10	SC3	SC11
8	SC9	SC9	SC9	SC4	SC5	SC5
9	SC4	SC3	SC3	SC3	SC4	SC4
10	SC5	SC11	SC11	SC5	SC1	SC10
11	SC10	SC5	SC10	SC11	SC10	SC1

Note: Red values in the table, indicate that two policy scenarios in the same column are equivalent.

Policies SC2 and SC6 achieve the first and fifth positions in the EWFE+, while in EWFE- they exchange the position of the ranking. SC2 has a greater positive impact than SC6 (three of the four criteria), however expert considered that SC6 has no negative impact while SC2 may have a slight negative impact on energy security. In fact, experts showed more variability of opinion when assessing the positive impact than the negative ones, so the ranking based on negative impacts (EWFE-) could not detect differences between six policies that according to the experts have almost no negative impact on the EWFE.

TOPSIS multi-criteria analyses on cross-cutting criteria, when these have equal importance, ranks policy SC6 (ensure energy efficiency in

Table 6
Correlations between the EWFE nexus and the cross-cutting criteria.

	Water	Food	Energy	Ecosystem
ISEG	0.16	0.57	0.47	0.13
ICCR	0.77	0.20	0.59	0.81
IGE	0.67	−0.11	0.74	0.78
IER	0.67	0.04	0.49	**0.85**

Correlation is significant at the 0.05 level.

buildings; column CS+ in Table 7) has having the best positive impact and also being among the least negative impacts (column CS− in Table 7). Policies SC1 and SC7 follow SC6 closely among the best ranking ones in both positive and negative impacts. SC10, SC9 and SC11 have the lowest positive impact (CS&v+ and CS&v−), while SC5 and SC11 have the highest negative impact.

Positive impact ranking across the two dimensions (CS+ vs EWFE+) shows good agreement regarding SC1 and SC10, but some disagreement about SC6 or SC2. Under the EWFE+, SC2 scores very good in all criteria except in energy, i.e. the criterion for which SC6 scores very high (being intermediate for the other three criteria). Under the cross-cutting dimension, SC6 scores very well in all the criteria (no controversy according to this criteria dimension) instead SC2 ranks in position 5 to 6 in all criteria. Results on negative impacts across the two dimensions are very coherent. However, SC10 results as the worst policy for cross-cutting dimension, which is consistent with EWFE+ and SC+ but not with EWFE− ranking.

The consistency of the ranking across dimensions and impact direction is remarkable, and increase the confidence in the MCA results albeit based on a small group of experts. Results were robust also when changing weights to criteria accounting for correlations between them (Tables 2 and 4). For example, in the EWFE dimension, by reducing weights of Water and Ecosystem to 16.5% and increasing those of Energy and Food to 33.3% to account for correlation in the first two (Table 2), the scores varied slightly but the ranks of SCs remained equal. Sensitivity analysis on the criteria weights confirmed that ranking between policies changed only under very unbalanced conditions, i.e. when one criterion was much more prevalent over the others (see Fig. SM1 in the supplementary material). In the cross-cutting dimension, where correlation between criteria may risk introducing a bias, the weights of ICCR and IGE could be reduced to less than 0.1 and the PoS increased to be more than 0.4. In this case SC6 became the second best alternative following SC7 (see Fig. SM3 in the supplementary material), but SC10 still remains the worst scenario. A change of ranking for SC10 could only happen in an extremely unbalanced setup (weights for ISEG > 0.45, ICCR < 0.1, IGE < 0.1, IER < 0.2 and probability of success < 0.15; see Fig. SM4 in the supplementary material).

Finally, experts consider that the most positive policy according to EWFE+ indicator (SC2) has a high probability to be implemented successfully. The same applies also to best policies SC8 and SC7. Conversely, experts believe that one of the most positive policies (SC1, restoring ecosystem and green infrastructures) according with all indicators (based on EWFE or SC surveys) is unlikely to be successfully implemented in the region.

4. Discussion and conclusion

It is very difficult to assess all positive and negative impacts of sectoral policies outside their direct field of application. A more integrated perspective, such as the Ecosystem Water Food Energy (EWFE) or the cross-cutting dimensions, may help weight pros and cons of each policy in the larger context. MCA provides a structured framework for combining expert judgement about alternative options against a set of decision criteria and allows participation of multiple stakeholders, from governments to NGOs or lay citizens. The use of different criteria may lead to more informed and better decisions.

The correlation analysis helped detecting potential synergies or conflicts (Lawrence and Lin, 1989; Füssel, 2009) between criteria and SCs. IER, ICCR and IGE were found to be affected by the same SCs in a similar way, since the possibility of the ecological resilience redounds positively up the green economy and climate change resilience. Thus three of the four cross-cutting criteria share a common basic principle of ecology or sustainability, which however remains unexpressed. Conversely, the fourth pillar of Ecosystems in the EWFE Nexus dimension makes explicit reference to the role of ecosystem services. EWFE performed better than cross-cutting criteria to detect potential synergies or conflicts between sector policies because it provided a more holistic and balanced framework.

In terms of synergies and conflicts among policies, a negative correlation was detected between SC1-SC10 in the EWFE, but not in the cross-cutting strategies analysis. Conversely, SC7 and SC8 (increase solar and wind energy) have significant positive correlations in both dimensions. We must also bear in mind that the analyses try to detect policies in conflicts between sectors. Where a policy is negative for a greater number of sectors, it will be penalized in the ranking. However, it is possible that the benefits of a policy in one sector are higher (or much higher) than the negative impacts in the other sectors.

A limit of this study is that it relates to the judgment of a relatively small group of experts, thus results are conditioned by the expertise of respondents, and their cultural background (Keeney and Raiffa, 1993). Results of this study must therefore be considered exploratory, to be confirmed by further research that should involve a larger and more representative sample of experts and stakeholders. Further, quantitative studies about impacts of policies in other sectors should be conducted to verify experts' perceptions.

We conducted MCA giving equal weights to all criteria to take a neutral stance when conducting the analysis, recognizing equal importance among sectors; however, the robustness of multi-criteria analysis is confirmed by considering two dimensions and impact direction of the multiple analysis (Table 7). The ranking of policies obtained in all MCAs is highly consistent, although the order of the SCs changed slightly. A group of best performing policies (SC1, SC2, SC6, SC7 and SC8) according to the expert opinion could be identified in Table 7. SCs that negatively impacted some cross-cutting or nexus criteria (SC3, SC5, SC10, and SC11) could be concurrently listed.

The probability of successful implementation of a policy and its ranking may differ depending upon the environmental and social-cultural conditions; however the group of the best performing policies has also the highest probability of successful implementation with the one remarkable exception of SC1. The SC1, restoring ecosystem and green infrastructures policy ranks second in almost all (in one case it gets the third) analysis performed, but according to the experts its probability of successful implementation is among the lowest. According to the additional comments provided by the experts, this is linked to the lack of awareness among communities and policy makers in the region on the importance and benefits of ecosystem services.

Sustainable use of ecosystem services and conserving biodiversity may thus be a key policy towards successful management of the multiple sectors that share the use of natural resources, but this has become apparent only under an integrated, more holistic, multi-sectoral framework.

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Appendix A. Supplementary data

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